Quiet Pavement Testing in B.C. (1995-2004)

A Presentation for:

ADC40 Noise & Vibration Summer Meeting

Seattle WA,

July 17-20, 2005

Presentation By:

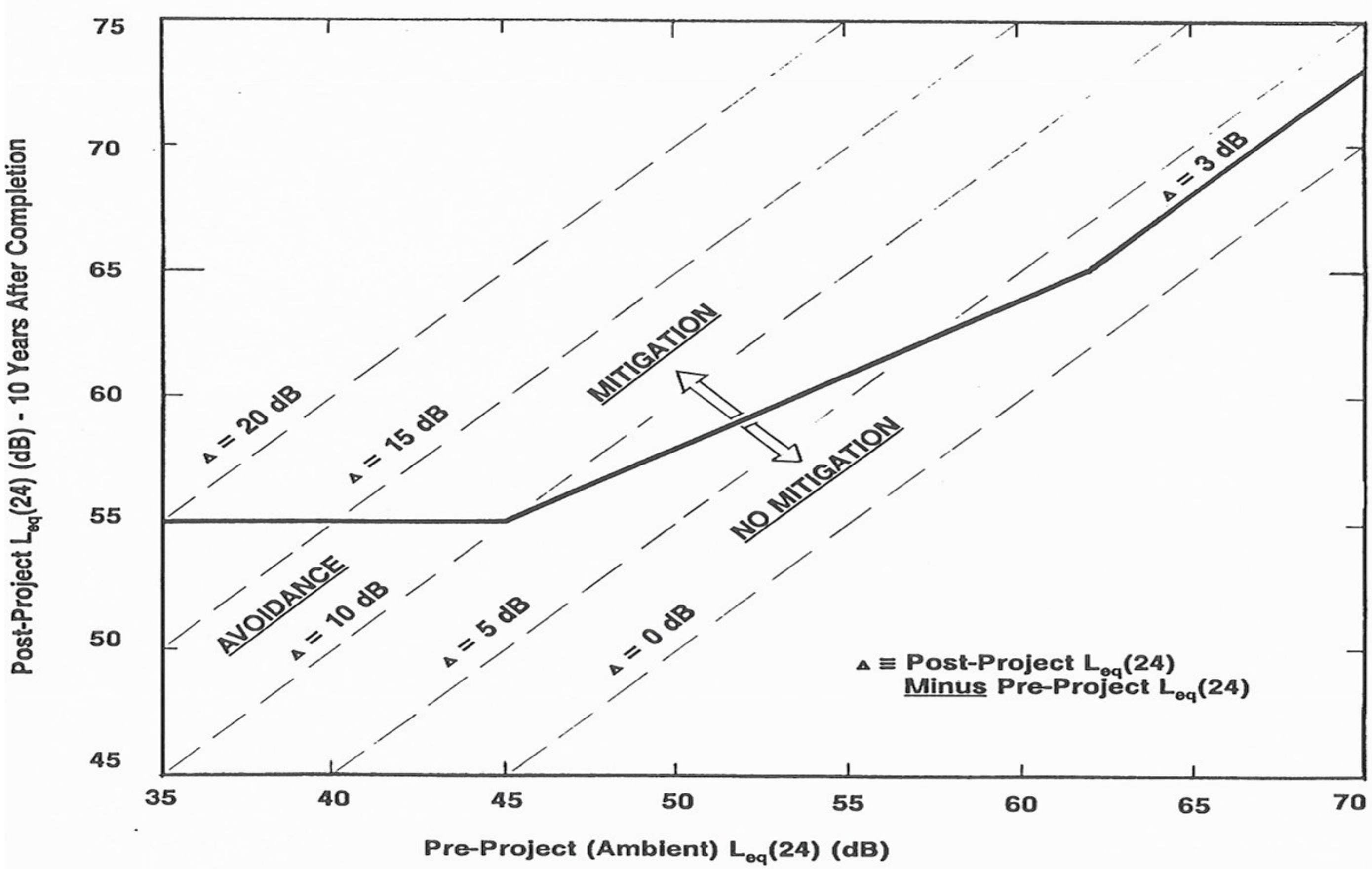
Duane Marriner
Wakefield Acoustics
Suite 301
2250 Oak Bay Avenue
Victoria, B.C., Canada
Tel: 250/370-9302
E-mail: duane@wakefieldacoustics.com

Quiet Pavement Testing Motivation:

- A B.C. Ministry of Transportation Policy (1993) criterion is that:
  - mitigation must be feasible providing a 5 dBA noise reduction benefit.
- Do quiet pavement(s) meet the criterion?
  - (Needs to be fully substantiated)

B.C. Ministry Of Transportation:

Revised Policy for Mitigating the Effects of Traffic Noise from Freeways and Expressways (1993)



Pre-Project	Post-Project	Increase
≤ 45	55.0	≥10.0
46	55.6	9.6
47	56.2	9.2
48	56.8	8.8
49	57.4	8.4
50	58.0	8.0
51	58.5	7.5
52	59.1	7.1
53	59.7	6.7
54	60.3	6.3
55	60.9	5.9
56	61.5	5.5
57	62.0	5.0
58	62.6	4.6
59	63.2	4.2
60	63.8	3.8
61	64.4	3.4
62	65.0	3.0
63	66.0	3.0
64	67.0	3.0
65	68.0	3.0
etc...		

Figure 1: Graphical Representation of MoTH Noise Policy Criteria for Residences, (MoTH, 1993)

Quiet Pavement Testing in B.C.

Objective:

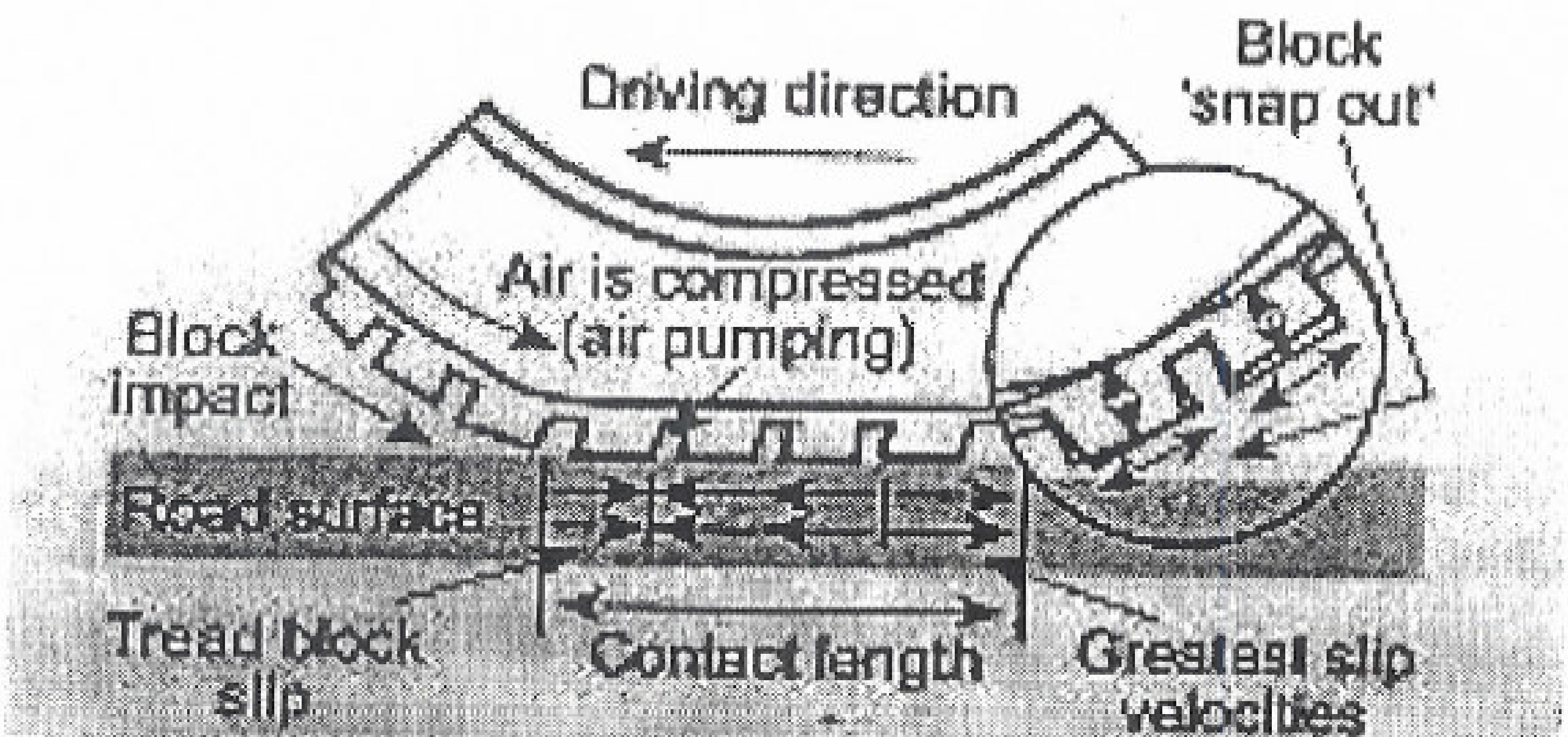
Compare tire-pavement-interaction noise emissions from Conventional Pavement(s) with emissions from Quiet Pavement(s) at highway (cruise) speeds.

Noise Source
Tire-Pavement-Interaction
(Wakefield Acoustics Ltd, 2001)

- Impact and shock,
  - Collision of tire tread with aggregate,
- Aerodynamic processes,
  - “Suction cup” effect called air-pumping,
- Adhesion and micro-movement,
  - “Slip-stick” mechanism associated with tire contact patch deformation.

Figure 2:

Tire-Pavement-Interaction Noise Generation Mechanisms:



(Source unknown)

Quiet Pavement Noise Reduction Effects:

(Wakefield Acoustics Ltd., 2001)

- Rubber content of Asphalt Rubber Concrete (ARC) reduces pavement stiffness which may act to reduce:
  - impact and shock mechanism,
  - "slip-stick" mechanism,
- Voids within porous ARC pavement(s) as well as Open Graded Asphalt(s) (OGA and OGFC) and "Superpave(s)" act to defeat air-pumping mechanism,
- Some added benefits:
  - heavy vehicle tire whine has been observed to be substantially reduced (half as loud for some tire tread patterns) with ARC and OGA,
  - reduction of other roadway noise sources (engine, exhaust)
    - phase cancellation may occur between direct roadway noise and noise able to "bounce" from porous pavement (possible "ground effect") as well as absorption.

Quiet Pavement Testing in B.C. (1995 – 1999)

- *"Before-and-After"* Testing:
  1) **Used Conventional vs. New to Four Year Old OGA/**Highway 19 North Nanaimo/1995-99,
  2) **Used Conventional vs. New "Superpave"/** Highway 1 - Hunter Creek to Laidlaw - Fraser Valley/1999.
- *"Side-by-Side"* Testing:
  3) **New Conventional vs. New to Two Year Old OGA/**Duke Point Highway/1996-98,

Table 1:

Quiet Pavement Testing in B.C. Summary of Results

(Wakefield Acoustics Ltd., 1995-1999)

Type of Test	Pavement Types/Location	Date	Measured NR (dBA)
"Before and After"	**Used Conventional vs** **New to Four Year Old OGA/** Highway 19, North Nanaimo, B.C.	1995	4.9
		1996	4.7
		1997	~4.7
		1998	~4.7
		1999	~4.7
"Before and After"	**Used Conventional vs** **New "Superpave"/** Highway 1 Hunter Creek to Laidlaw - Fraser Valley, B.C.	1999	2.6
"Side by Side"	**New Conventional vs New to Two Year Old OGA/** Duke Point HighwayB.C.	1996	4.8
		1997	-
		1998	4.7

ARC Pavement Testing in B.C. (2004)

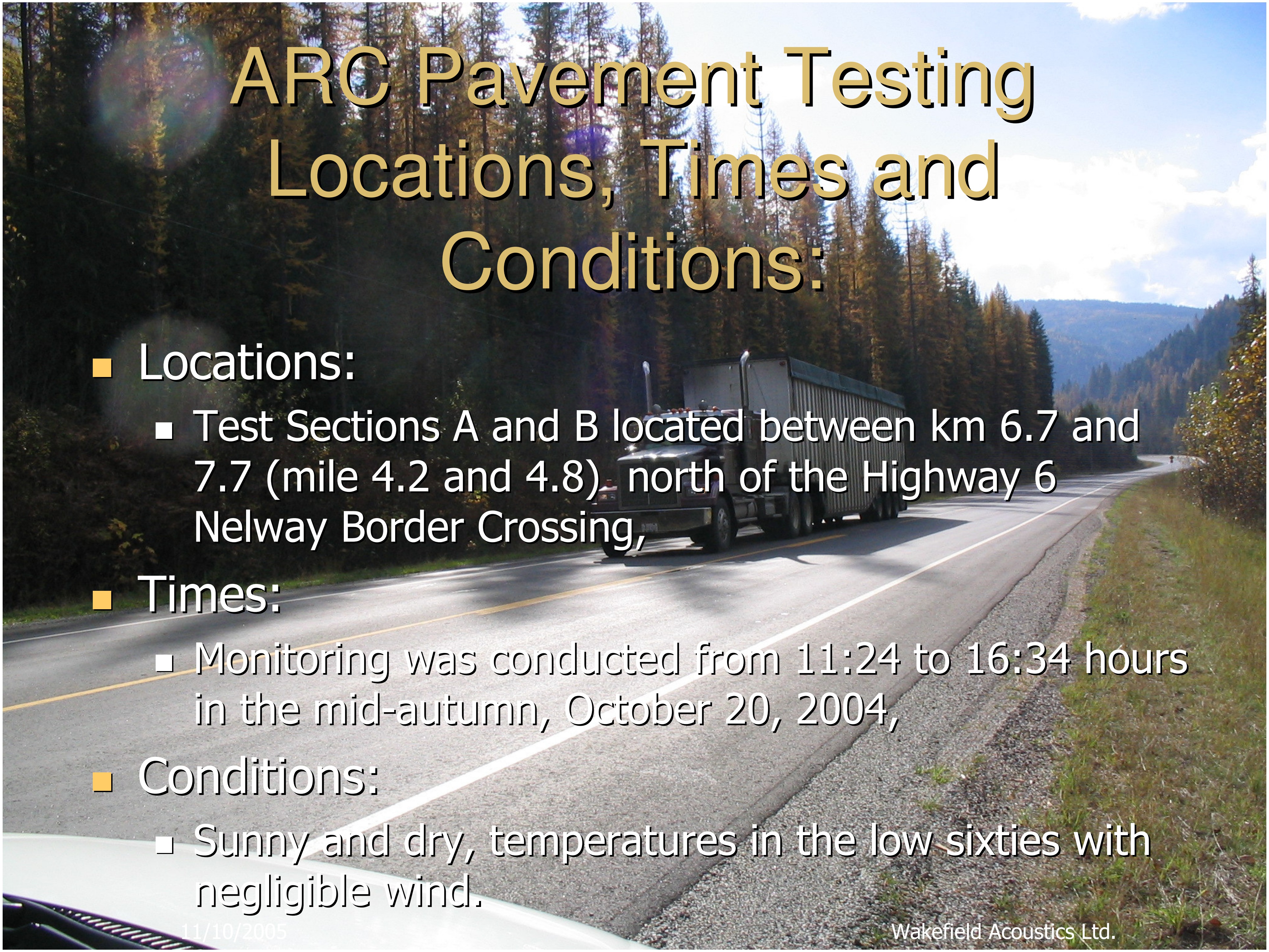
- *"Side-by-Side"* Testing:
  4) **New Conventional vs. New ARC**/Highway 6 Nelway B.C. Border Crossing/2004 (featured in background photo)**.**
  - What is ARC?:
    - ARC stands for Asphalt Rubber Concrete(s) or Crumb
    - Variations include but are not limited to
      - gap grade, open grade, ARFC, A-R OGFC.
  - Composition (by weight):
    - ARC contains 8% asphalt rubber binder (typical conventional contains 6% asphalt cement)
      - rubber content of binder 20%
    - net effect ARC is 1.5% rubber by weight (aci, 2005).

Test Section A (White CL) Specifications:

- Pavement Type: New Conventional
  - Length: 500 m (0.311 miles)
  - Composition:
    - Top lift 37.5 mm to 50 mm (1.5 to 2 inches, reduced) conventional Class I medium mix with conventional 150/200 asphalt cement,
    - Bottom lift 50 mm (2 inches) conventional Class I medium mix with MoT’s conventional 150/200 asphalt cement.

Test Section B (Amber CL) Specifications:

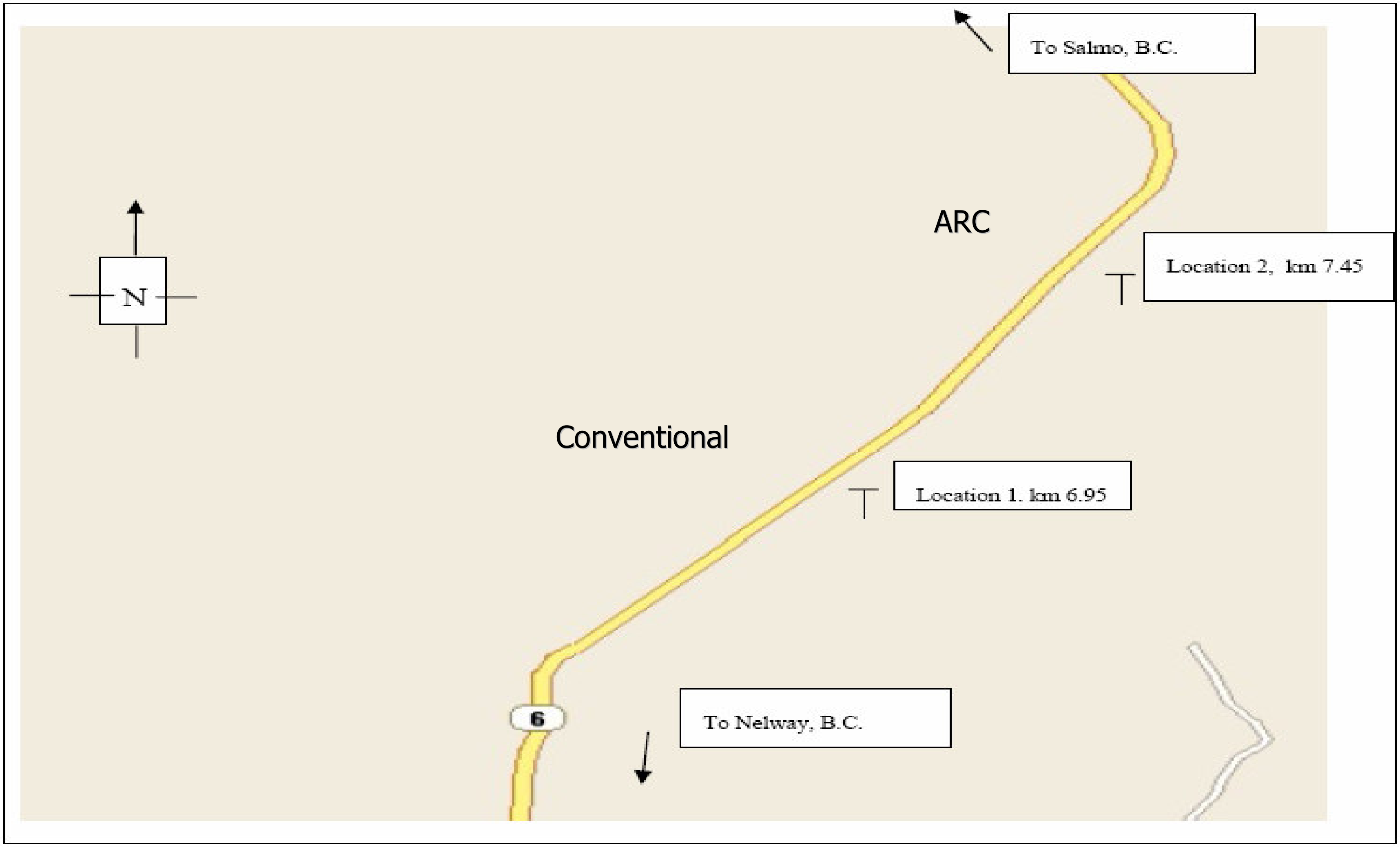
- Pavement Type: Asphalt Rubber Concrete (ARC)
  - Length: 500 m
  - Composition:
    - Top lift 37.5 mm (reduced) conventional Class I medium mix with 200/300 asphalt cement ,
    - Bottom lift 50 mm conventional Class I medium mix with conventional 150/200 asphalt cement.



ARC Pavement Testing Locations, Times and Conditions:

- Locations:
  - Test Sections A and B located between km 6.7 and 7.7 (mile 4.2 and 4.8) north of the Highway 6 Nelway Border Crossing,
- Times:
  - Monitoring was conducted from 11:24 to 16:34 hours in the mid-autumn, October 20, 2004,
- Conditions:
  - Sunny and dry, temperatures in the low sixties with negligible wind.

Site Map:



Site Map of Highway 6 Test Sections, Nelway to Jct. Highway 3, B.C.

ARC Pavement Testing Methodology:

- Instrumentation:
  - Larson-Davis 812/820 Community Noise Analyzers (3),
  - Larson-Davis 2800 RTA (1).
- Metrics:
  - Leq(1 sec) → SEL (Sound Exposure Level),
  - Leq(1 min), Leq(5.2 hour)
  - Cumulative one-third-octave-band spectra for light and heavy vehicle categories.

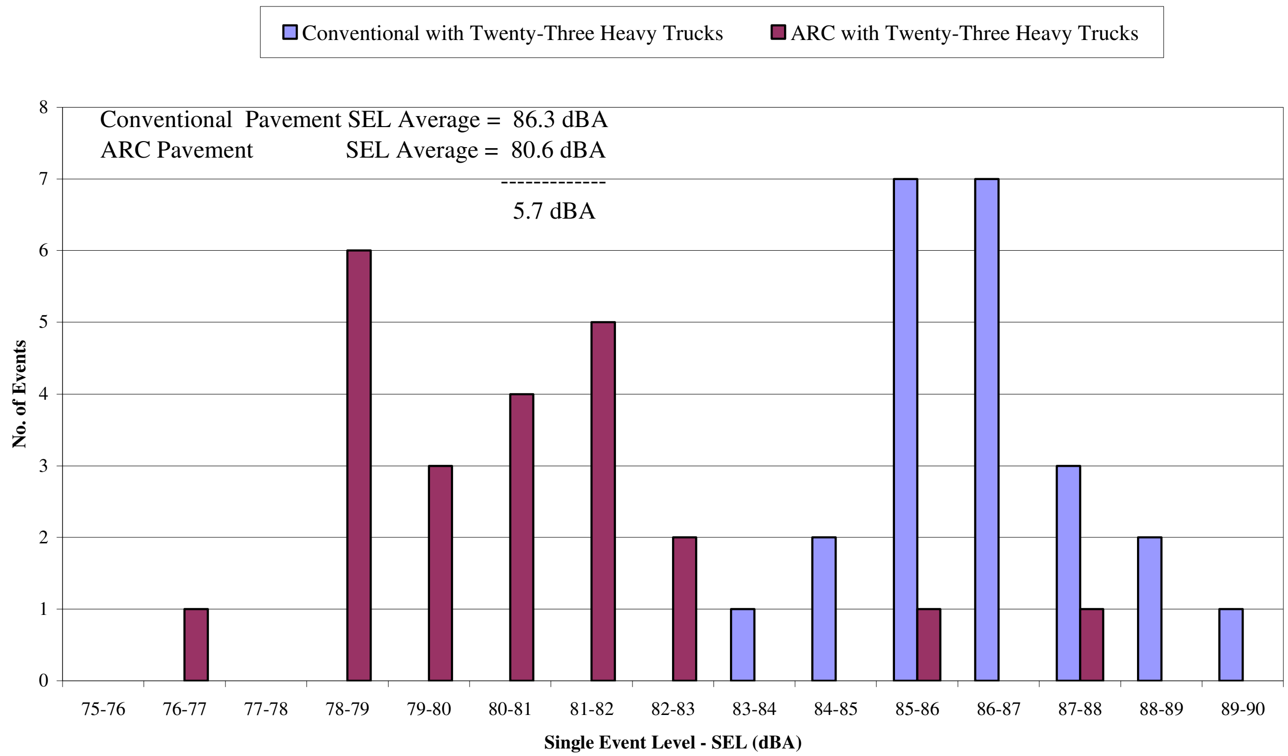
Table 2:

ARC Pavement Testing Traffic Mix:

Vehicle Category	Heavy Trucks	Automobile	Pick-up Trucks	SUV	Medium Trucks
Number of Pass-bys over 5.2 hours 11:25 to 16:33 hours on October 20	32	23	13	10	3
Average Time in Minutes between Pass-bys	10	14	24	31	104

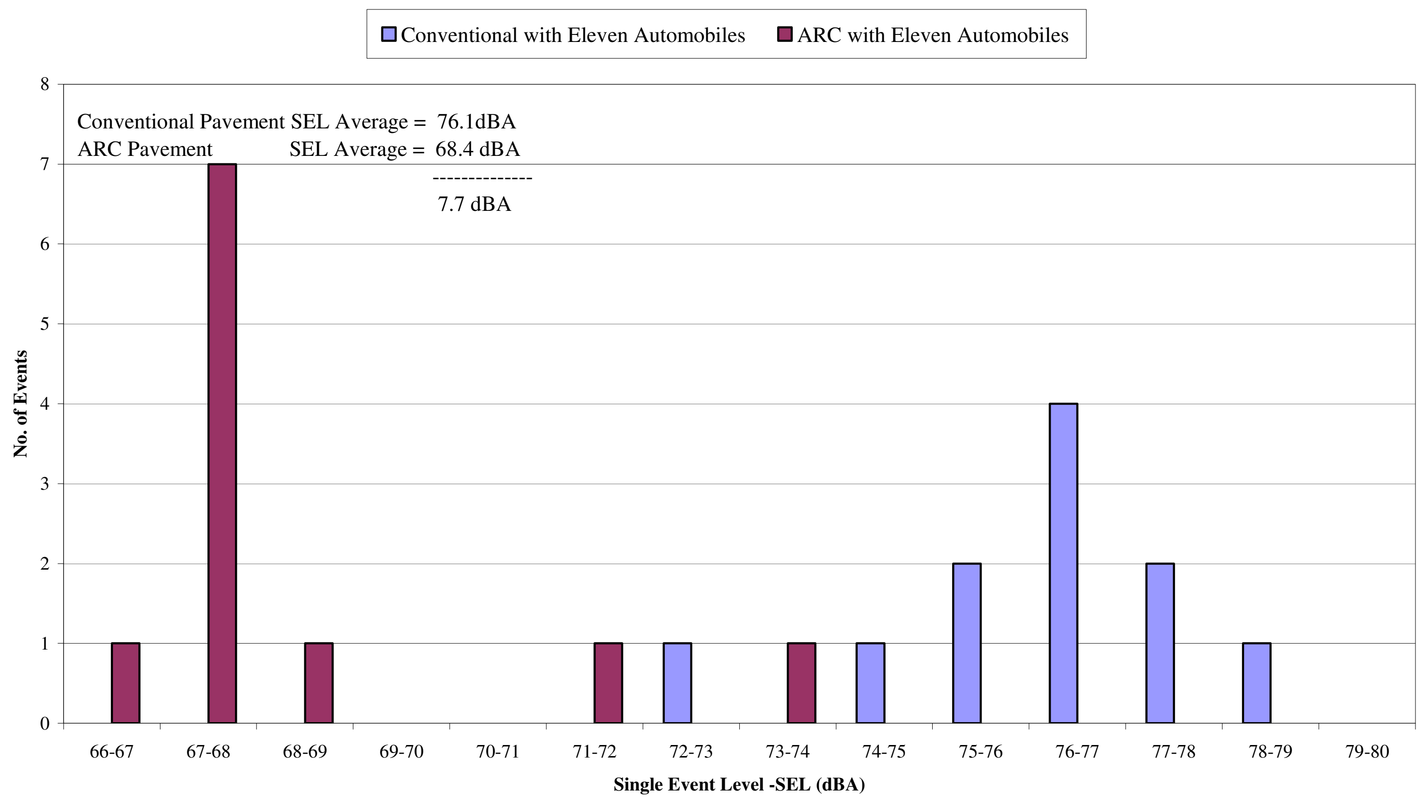
ARC Pavement Testing Results: Heavy Vehicle SEL Histogram:

Figure 3: **ARC Pavement Demonstration Project Highway No. 6 Nelway, B.C. / Manned Monitoring Results Conventional/ARC Test Sections, October 20, 2004**

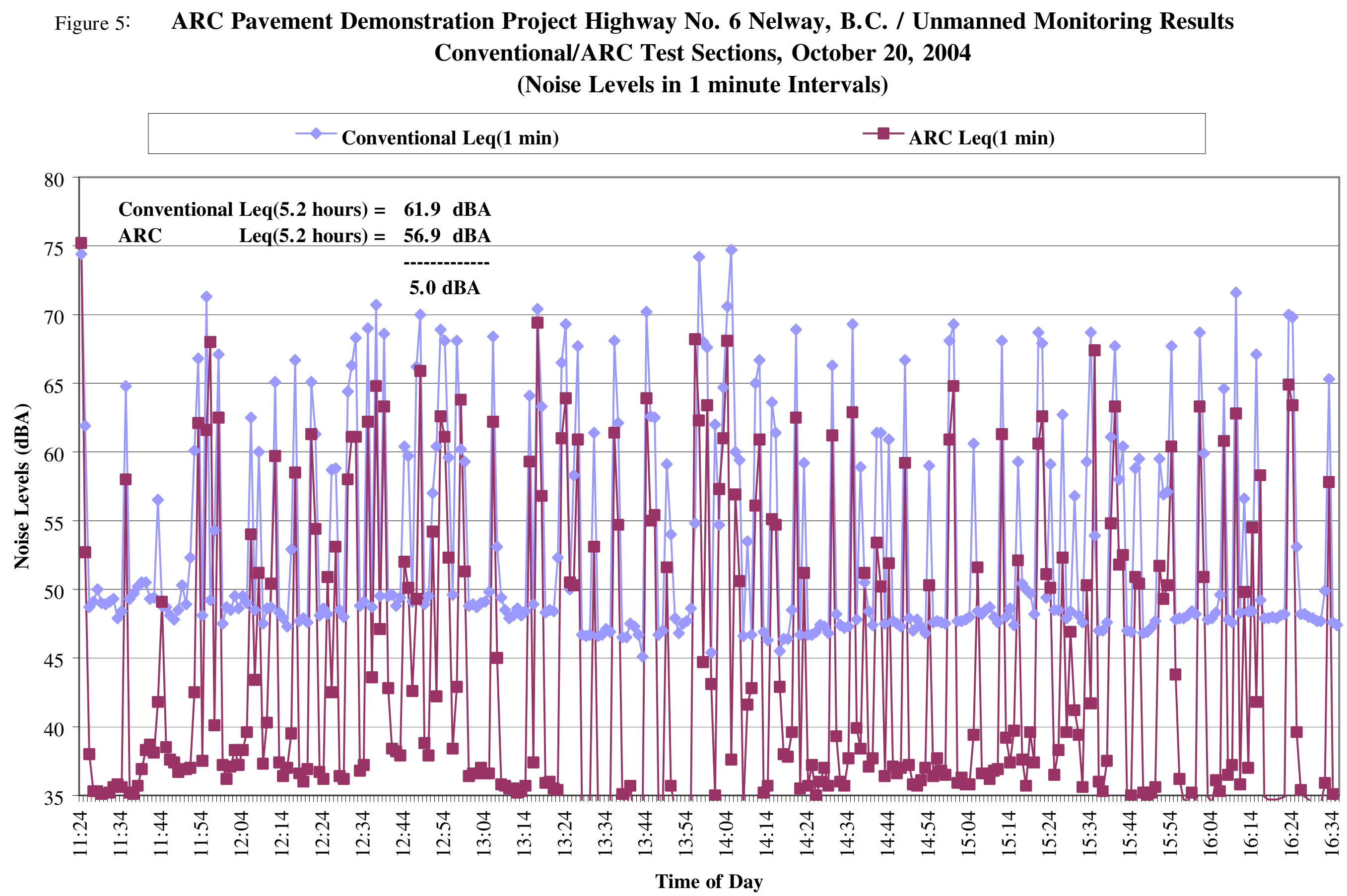


Light and Medium Vehicle SEL Histogram:

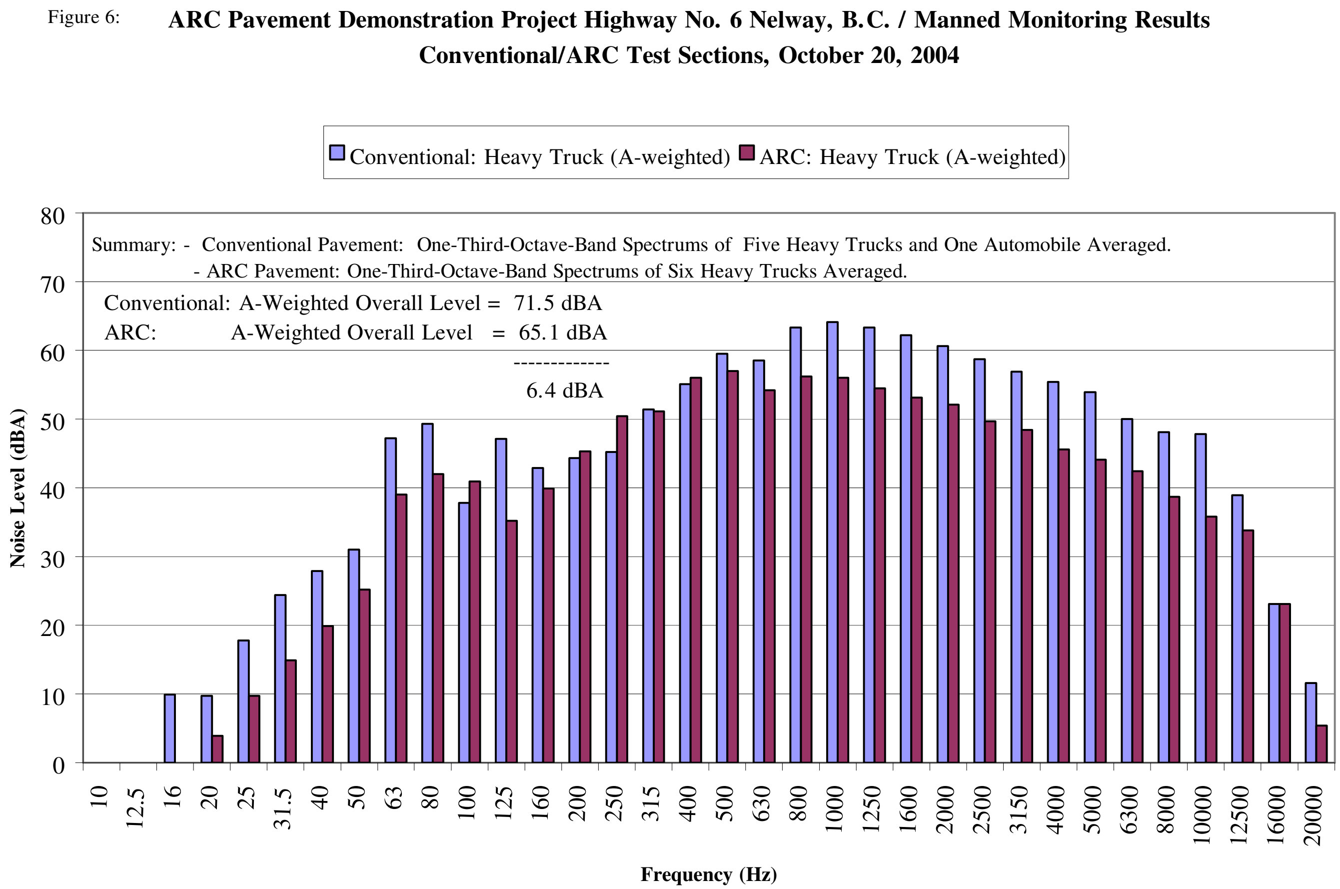
Figure 4: **ARC Pavement Demonstration Project Highway No. 6 Nelway, B.C. / Manned Monitoring Results**
Conventional/ARC Test Sections, October 20, 2004



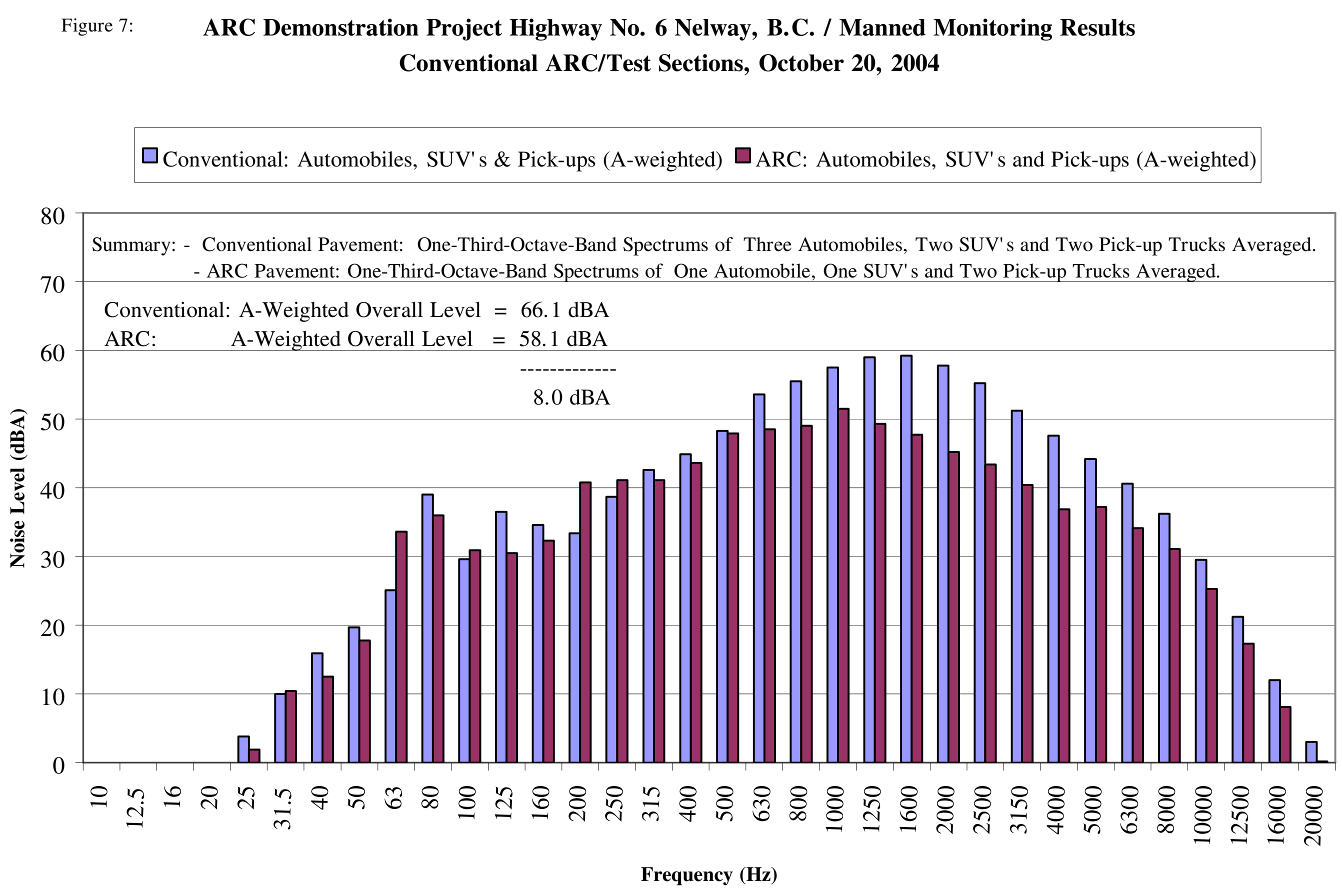
All Vehicle Categories
Leq (1 min) History over 5.2 Hours



Heavy Vehicles: One-third-octave Band Spectra



Light and Medium Vehicles: One-third-octave Band Spectra



ARC Pavement Testing Additional Observations:

Quantitative:

- Noise Reduction Benefit of ARC improved with vehicle speed, providing roughly 2.6 dBA more noise reduction with a speed increase of 40 km/hr (25 mph) - from 70 km/hr (43 mph) to 110 km/hr (68 mph).

Subjective:

- Tire whine was dramatically reduced with ARC up to half as loud with *some* heavy vehicle tread patterns.

Quiet Pavement Testing in B.C. Conclusions:

- OGA pavements tested provided a 4.7 dBA credit towards mitigation,
- OGA's long term acoustical performance was roughly constant over four years,
- ARC marginally met MoTH Policy (1993) criterion and provided a 5 dBA noise reduction benefit over conventional pavement for general traffic (ADT 370 vpd, HV Mix 40%), and in addition provided:
  - Greatest Noise Reduction Benefit for the Light to Medium Vehicle Class (except for Heavy Vehicle Tire Whine),
  - Substantial Noise Reduction in low frequency bands for the Heavy Vehicle Class,
  - Substantial Noise Reduction for Heavy Vehicle Tire Whine,
- ARC's noise reduction effectiveness diminishes with speed.

Future Quiet Pavement Testing:

- Further testing of ARC is required to,
  - fully substantiate the existing data,
  - establish long term acoustical performance of ARC,
- This could involve ARC Pavement Testing “Before-and-After”, “Side-by-Side” modes or a combination, with:
  - low ADT to:
    - establish noise reduction benefit for specific vehicle categories,
    - separate phenomena such as ARC’s absorptive properties,
  - high ADT to:
    - assess the performance of ARC with metrics such as the $L_{eq}(24)$ or the ISO 11819-1 SPBI.

Acknowledgements:

Sponsorship for the
ASPHALT RUBBER CONCRETE (ARC) PAVEMENT DEMONSTRATION PROJECT
Highway 6, Nelway, B.C.
was provided by the
B.C. Ministry of Transportation.

EBA Engineering of Edmonton Alberta is gratefully acknowledged for their support, assistance and creation of the Highway 6 test sections.

Motorists of B.C.

References:

- Ministry Of Transportation MoTH,
  Revised Policy for Mitigating the Effects of Traffic Noise from Freeways and Expressways (1993)
- Open Graded Asphalt and Super Pavements: Assessment of Traffic Noise Reduction Effects, prepared for the Ministry of Transportation of B.C. by Wakefield Acoustics Ltd. (2000)
- Highway Noise Assessment and Control, A Seminar Presented to EBA Engineering, prepared for EBA Engineering, Edmonton by Wakefield Acoustics Ltd. (2001)
- Tire Noise Assessment of Asphalt Rubber Crumb Pavement, Technical Note, 37 – Vol 33 No.1 Canadian Acoustics (2005)

References (cont'd.):

- Highway 6, Nelway, B.C. Asphalt Rubber Concrete (ARC) Pavement Demonstration Project – Noise Testing prepared for EBA Engineering, Calgary by Wakefield Acoustics Ltd. (2005)
- I-80 Davis OGAC Pavement Noise Study, Illingworth & Rodkin Inc. (2002)
- Two-Layer Drainage Asphalt-Noise Reduction and Clogging, Kragh et al, Inter noise (2001)
- Visualization of the Tire Vibration and Sound Radiation and Modeling of Tire Vibration with and Emphasis on Wave Propagation, Bolton and Kim, Institute of Safe, Quiet and Durable Highways, Report Number SQDH 2003-4 (2003)

Quiet Pavement Testing/ Practical Considerations:

- "Before-and-After" Testing:
  - Control "Before" pavement should be new conventional pavement but is often *used* and noisy conventional pavement,
    - increases apparent noise reduction benefit of the quiet pavement,
  - In the interim (between tests)
    - traffic volumes,
    - percent heavy vehicles,
    - running speeds,

  can change and affect the results either way.

Practical Considerations (cont'd.):

- "Side-by-Side" Testing:
  - Test sections should be,
    - adjacent,
    - straight and level,
    - both in a cut or both on fill,
  - Site bias should be minimized,
  - Noise consultant should be involved in site selection.

In general, test sections should be traffic noise dominated in suitable terrain with clear line of site from receiver to the tire-pavement contact patch.

Practical Considerations (cont'd.):

- Low ADT Testing (1000 or less vehicles per twenty-four hours) Advantages :
  - testing of,
    - different categories of vehicles,
    - control speed pass-by testing for different categories of vehicles,
    - effects of tread patterns,
    - heavy vehicle tire whine testing,
    - testing for the "Ground Effect",
    - absorption effect,

  are more easily completed on a low ADT test section.
- Low ADT Testing (1000 or less vehicles per twenty-four hours) Disadvantages :
  - difficult to implement ISO 18819-1 or measure Leq(24) if the traffic is sparse within one day.

Practical Considerations (cont'd.):

- High Regime ADT (8000 or more vehicles per twenty-four hours) Advantages:
  - testing using the ISO 11819-1 Standard[1] to establish the Statistical Pass-by Index (SPBI)[2] and the Leq(24) may be efficiently completed in one day.
- High Regime ADT (8000 or more vehicles per twenty-four hours) Disadvantages:
  - difficult to resolve individual vehicle pass-bys and classify emissions in terms of vehicle category,
  - difficult to conduct special tests of:
    - controlled speed pass-bys,
    - "Ground Effect" of quiet pavements,
    - assess absorptive properties of quiet pavements.

- [1] The SPBI calls for the testing of one hundred automobiles and eighty heavy vehicles and would require a higher ADT test section.
- [2] These tests require the use of a radar gun to determine the vehicle speed.